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HEAD SLIDER AND DISK DRIVE APPARATUS USING THE SAME		THE COMMISSIONER IS AUTHORIZED TO CHARGE ANY DEFICIENCY IN THE FEES FOR THIS PAPER TO DEPOSIT ACCOUNT NO. 23-0975

VERIFIED ENGLISH TRANSLATION OF PRIORITY DOCUMENT

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Sir:

Attached hereto is the verified English translation of Japanese Priority document 2000-372632, which was filed on December 7, 2000.

Respectfully submitted,

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CERTIFICATE

I, Tatsuyuki Tomioka of c/o Matsushita Technical Information Service Co., Ltd., Matsushita IMP Building 18F, 1-3-7, Shiromi, Chuo-ku, Osaka, 540-6318 Japan, hereby certify that I am the translator of the attached document;

Japanese Patent Application No. 2000-372632

and certify that the following is a true and correct translation to the best of my knowledge and belief.

At Osaka, Japan,

Date:

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[NAME OF THE DOCUMENT] SPECIFICATION

[TITLE OF THE INVENTION] HEAD SLIDER AND DISK RECORDING AND PLAYING BACK APPARATUS USING THE SAME

[CLAIMS]

What is claimed is:

1. A head slider comprising:

an opposing face opposing a disk-formed recording medium;

an air inlet end;

an air outlet end;

a disk inner edge side; and

a disk outer edge side;

said opposing face includes:

a positive pressure generating section;

a negative pressure generating recess;

an information transducer device disposed at said air outlet end for performing at least one of recording operation and playing back operation on said disk-formed recording medium; and

a sloped face extending from end on an air outlet side of said negative pressure generating recess to at least one end of ends at said air outlet end, said disk inner edge side, and said disk outer edge side, and being arranged such that a distance from said disk-formed recording medium is gradually larger toward the ends while said head slider opposing said disk-formed recording medium.

2. A head slider comprising:

an opposing face opposing a disk-formed recording

medium;

an air inlet end;

an air outlet end;

a disk inner edge side; and

a disk outer edge side;

said opposing face includes:

a positive pressure generating section;

a negative pressure generating recess;

an information transducer device disposed at said air outlet end for performing at least one of recording operation and playing back operation on said disk-formed recording medium; and

a through hole extending from said negative pressure generating recess to an end face at said disk inner edge side or an end face at said disk outer edge side.

3. The head slider according to claim 1 or 2, wherein said opposing face opposing said disk comprises two air-bearing faces, said two air-bearing faces include:

a first air-bearing face; and

a second air-bearing face,

said first air-bearing face includes:

a positive pressure generating section;

a negative pressure generating recess; and

an information transducer device disposed at said air outlet end;

said second air-bearing face includes:

a sloped face extending from end on an air outlet side of said negative pressure generating recess to at least one end of ends at said air outlet end, said disk inner edge side, and said disk outer edge side, and being arranged such that a distance from said disk-formed recording medium is gradually larger toward the ends while said head slider opposing said disk-formed recording medium .

4. The head slider according to any one of claims 1 to 3, wherein said positive pressure generating section including:

two side rails disposed at a predetermined distance from each end of ends at said disk inner edge side and said disk outer edge side so as to be extended from said air inlet end towards said air outlet end; and

a cross rail disposed at a predetermined distance from said air inlet end and arranged perpendicularly to the air inflow direction and connected with said two side rails;

said negative pressure generating recess including: a lower-leveled face, said lower-leveled face surrounded by said positive pressure generating section and a flotation improving face, said flotation improving face is formed in a central portion at said air outlet end, separately from said positive pressure generating section.

5. The head slider according to claim 1 or 3; wherein

said sloped face is a tapered face extending from the end on an air outlet side of said negative pressure generating recess to said air outlet end such that a distance from said disk is gradually larger toward said air outlet end while said head slider opposing said disk.

6. The head slider according to claim 1 or 3; wherein

said sloped face is a curved face extending from the end on the air outlet side of said negative pressure generating recess to at least one end of ends at said air outlet end, said disk inner edge side, and said disk outer edge side, and arranged such that a distance from said disk changes continuously larger toward the ends while said head slider opposing said

disk.

7. A disk recording and playing back apparatus comprising:

a disk serving as a recording medium;

a driver for rotationally driving said disk;

a suspension capable of swinging and having a head slider attached to a tip of said suspension such that said head slider faces said disk; and

a retreat position where said head slider is held retreated when said disk is stopped;

said head slider includes:

an opposing face opposing said disk;

an air inlet end;

an air outlet end;

a disk inner edge side; and

a disk outer edge side;

said opposing face includes:

a positive pressure generating section;

a negative pressure generating recess;

an information transducer device disposed at said air outlet end; and

a sloped face extending from end on an air outlet side of said negative pressure generating recess to at least one end of ends at said air outlet end, said disk inner edge side, and said disk outer edge side, and being arranged such that a distance from said disk-formed recording medium is gradually larger toward the ends while said head slider opposing said disk-formed recording medium.

8. A disk recording and playing back apparatus comprising:

a disk serving as a recording medium;

a driver for rotationally driving said disk;

a suspension capable of swinging and having a head slider attached to a tip of said suspension such that said head slider faces said disk; and

a retreat position where said head slider is held retreated when said disk is stopped;

said head slider includes:

an opposing face opposing said disk;

an air inlet end;

an air outlet end;

a disk inner edge side; and

a disk outer edge side;

said opposing face includes:

a positive pressure generating section;

a negative pressure generating recess;

an information transducer device disposed at said air outlet end; and

a through hole extending from said negative pressure generating recess to an end face at said disk inner edge side or an end face at said disk outer edge side.

[DETAILED EXPLANATION OF THE INVENTION]

[0001]

[FIELD OF THE INVENTION]

The present invention relates to a head slider mounting a device for recording and playing back a signal on a disk-formed recording medium such as a magnetic disk or an optical disk, and to a disk recording and playing back apparatus using the same.

[0002]

[BACKGROUND OF THE INVENTION]

There have been made great advances in apparatuses for recording and playing back signals on disk-formed recording media (hereinafter called "disk") such as hard disks or optical disks. For example, the recording density of a hard disk apparatus has been increasing at a rate of close to 100% every year. In order to increase the recording density further, it is required that the space between the disk surface on which signals are recorded and the head slider on which the head is mounted, i.e., the flying height be decreased further. More concretely, a stable realization of a flying height below 20 nm is required.

[0003]

To realize such a minute flying height, the head slider, a mechanism for loading and unloading the head slider, or a structure of a surface of the disk are devised. As a mechanism for loading and unloading the head slider for conventional recording and playing back apparatus, a Contact Start Stop (CSS) system has being widely used. The CSS system is such that the head slider in contact with the surface of the disk flies while sliding on the disk surface when the disk recording and playing back apparatus startups, and the flying head slider stops while sliding on the disk surface when the apparatus stops. Therefore, the apparatus does not startup normally sometimes, as the head slider adheres to the disk if the disk surface is smooth-surfaced, because the head slider is kept in contact with the surface of the disk when the apparatus stops. In order to prevent occurrence of such adhesion, bumps and dips generally called "texture" are provided on the surface of the disk. Because the head

slider is required to fly while keeping a distance to avoid contact with the bumps and dips of the texture. the CSS system had a limit to realization of a lower flying height.

[0004]

As a method to prevent a head slider from adhering to a smooth-surfaced disk, a mechanism for loading and unloading the head slider of a Non-Contact Start Stop (NCSS) system is being paid attention. The NCSS system is such that allows the head slider to be lifted up from the disk surface and held to a retreat position while the disk stops and the head slider is shifted from the retreat position and flies normally after lifting down to the disk surface while the disk is rotated at a predetermined number of revolutions. As an example of the described mechanisms, there is that of a ramp loading type. The mechanism of this type is such that allows the head slider to be retreated to a retreat position of a sloped face called ramp at a predetermined location near the outer edge surface of the disk while the disk rotation is stopped, whereby the head slider is kept out of contact with the disk surface. Fig. 10 shows a perspective view of a disk recording and playing back apparatus using a ramp loading type in a condition of removing a housing cover. Disk 2 is supported by main spindle 1 and rotates with driver 4. As this driver 4, a spindle motor for example is used. Head slider 3 and tab 9 for loading are supported on suspension 10. This suspension 10 is fixed to actuator arm 5 and actuator arm 5 is rotatably attached to actuator shaft 7. Voice coil motor 6 swings actuator arm 5 and shifts head slider 3 with an information transducer device (not shown) attached thereto to a predetermined track position. In a predetermined position near the outer edge of disk 2, retreat position 8 with a slope called a ramp is provided.

[0005]

In the disk recording and playing back apparatus, disk 2 rotates in the direction indicated by arrow A in association with main shaft 1 by driver 4. In a stationary operation of head slider 3 flying over the rotating disk 2, actuator arm 5 is swung by voice coil motor 6 and the position of head slider

3 is determined and an information transducer device (not shown) records or reproduces a signal at a predetermined track.

[0006]

Loading/unloading operations in the disk recording and playing back apparatus on this system will be described. Unloading operation is performed as follows. Head slider 3 flying over disk 2 driven by voice coil motor 6 moves in the direction of ramp of retreat position 8 provided in a predetermined position in the vicinity of the outer edge of disk 2. Tab 9 for loading attached to suspension 10 lands on retreat position 8, whereby head slider 3 is retreated from disk 2. Loading operation is performed as follows. In a situation of disk 2 rotating around main shaft 1 by a driving means 4, actuator arm 5 is swung toward the inner side of disk 2 by voice coil motor 6 and head slider 3 is separated from retreat position 8 and set afloat over disk 2, whereby a steadily afloat situation for disk recording and playing back operation is obtained.

[0007]

In such a disk recording and playing back apparatus, a head slider of negative pressure is mainly used. The head slider of this type is configured to obtain a predetermined flying height by virtue of equilibrium of three forces as mentioned below. The first of the forces is that of a load from a suspension supporting the head slider. The second is a positive pressure due to an air flow produced by the disk rotation so as to float the head slider. The third is a negative pressure generated at a recess provided in the head slider so as to pull the head slider back to the disk. However, there has been problems as mentioned below in the use of negative pressure head sliders in a system which the head slider is pulled up from the disk surface and displaced to a retreat position as, for example, in the ramp loading method. Namely, at the time of unloading, even when the load from the suspension is eliminated, the negative pressure does not immediately decrease. Therefore, an extra lifting load to overcome the negative pressure is needed. Further, a greater lifting distance is needed. It was difficult to make the apparatus smaller and thinner and to allow it a

faster unloading operation. Further, when the head slider is shifted from the retreat position to over the surface of the disk so as to be set steadily afloat, the attitude of the head slider tends to become unstable when it is pulled down toward the disk surface and it sometimes occurs that the head slider collides with the surface of the disk to damage it.

[0008]

A head slider for quickly decreasing the negative pressure at the time of unloading is disclosed in JP2001-21111. Fig. 11A is a plan view of the head slider seen from the face opposing the disk. Fig. 11B is a sectional side view showing the relationship between head slider 3 and disk 2 in the state of head slider 3 being afloat over the outer edge portion of disk 2 before being unloaded. In Fig. 11A and Fig. 11B are also shown positive pressure Fp, negative pressure Fn, and load Fs from the suspension (not shown), acting on head slider 3 as well as their respective points of application Pp, Pn, and Ps of the pressures. The head slider 3 is held by a suspension (not shown) through a gimbal (not shown) and receives load Fs by means of a pivot (not shown) located at point of application Ps. Negative pressure generating section 74 has a deep step surrounded by protruded portions on both sides 72, is of a structure of having an opening at its outlet end. Air inflow from both sides is prevented by the portions on both sides 72 and thereby the efficiency of generation of negative pressure is enhanced. At each tip of the portions on both sides 72 on the outlet side of airflow, there are provided closer-to-disk faces 71 which are slightly higher than the portions on both sides 72. An information transducer device 80 is disposed on one of closer-to-disk faces 71. Positive pressure generating section 73 is made up of shallow-stepped portion 73a at the same level as the portions on both sides 72 and inlet-side closer-to-disk face 73b at the same level as closer-to-disk faces 71. Between positive pressure generating section 73 and negative pressure generating section 74, there is provided setting region 76 at the same level as the portions on both sides 72. By adjusting the width (SW) of setting region 76, the point of application Pn of negative pressure is set on the outlet side of the point of application Ps of suspension load. The transition from the condition of head slider 3 steadily

floating over rotating disk 2 to the condition of head slider 3 being unloaded takes place in this way: namely, when load Fs from the suspension is decreased, an angular moment is generated by the positive pressure and the negative pressure, the pitch angle of head slider 3, i.e., the angle formed between head slider 3 and the surface of disk 2 increases quickly. Hence, the gap between inlet-side closer-to-disk face 73b and disk 2 is rapidly increased. As a result, the amount of air flow taken from the inlet side into the space between head slider 3 and disk 2 is increased to quickly decrease negative pressure Fn of outlet side. Accordingly, adhesion of head slider 3 to disk 2 due to the production of negative pressure at the time of unloading can be suppressed and a stabilized unloading operation can be performed with a minimum required height of the ramp at the retreat position.

[0009]

[Problems to be Solved]

However, in the above-described mechanism to increase the pitch angle by making use of the angular moment to thereby decrease the negative pressure, there is a possibility of occurrence of an excessive angular moment, which is applied to head slider 3 to cause head slider 3 to come into contact with disk 2. When, for example, an external shock is given to the disk recording and playing back apparatus, while load Fs from the suspension is being decreased for making unloading, so that head slider 3 is caused to approach disk 2, then positive pressure Fp increases immediately but negative pressure Fn changes slower than the change of positive pressure Fp. That is, such a state is brought about in which, while load Fs from the suspension is decreased, positive pressure Fp increases and, nevertheless, negative pressure Fn dose not change so much. In this state, the angular moment applied to head slider 3 becomes greater than usual. Hence, the air outlet side of head slider 3 comes into contact with disk 2 so that head slider 3 or disk 2 sometimes suffers damage.

[0010]

When power supply to a disk recording and playing back apparatus

is cut off by mistake, it is required that the unloading operation be completed before the rotation of disk 2 is stopped. When an unloading operation is performed in such an unstable state with the rotational speed of disk 2 decreased, then, though the positive pressure decreases with the decrease in the air flow velocity, the negative pressure does not decrease keeping pace with the decrease in the positive pressure. Hence, an angular moment is produced and there arises a possibility of the air outlet side coming into contact with disk 2. When point of application Pn of negative pressure Fn is set on the downstream side of the point of application Ps of load Fs from the suspension, the pitch-angle rigidity, i.e., degree of stability against change in pitch angle, decreases. Therefore, head slider 3 comes to easily vibrate when subjected to external disturbance such as an impact.

[0011]

Further, in the loading operation to move the head slider from the retreat position to over the disk surface, it is generally required to allow the head slider, which is supported by a suspension made of an elastic member, to be set afloat over the disk surface without being damaged. In the head slider of the ramp loading type as described above, the loading is performed from the ramp portion, and hence a relatively stable floating operation can be realized. However, in the case of such a type on the NCSS system in which the head slider is brought to over the disk surface and, then, set afloat while it is pushed downward, the effect of vibration of the suspension cannot be sufficiently eliminated and a stabilized floating motion is difficult to attain. For example, the pitch angle of the head slider when it is steadily afloat over a disk is generally 0.1 mrad or so. On the other hand, when the suspension vibrates while the head slider is pushed down, it can occur that the head slider is loaded over the disk surface at a pitch angle greater than 1 mrad. When such a great pitch angle is produced, the end of the head slider can come into contact with the disk to cause damage, before a gap to provide a sufficient positive pressure is secured between the positive pressure generating section and the disk.

[0012]

The invention provides a head slider and a disk recording and playing back apparatus using the same capable of high speed loading/unloading by preventing the head slider from contacting the disk and by securing the stable pitch rigidity even with external disturbance, in a load/unload mechanism of NCSS system which the disk slider is kept held retreated when the disk recording and playing back apparatus is stopped.

[0013]

[Means to Solve the Problems]

To solve the above-mentioned problems a head slider of the invention includes an opposing face opposing a disk; an air inlet end; an air outlet end; a disk inner edge side; and a disk outer edge side. The opposing face opposing the disk includes: a positive pressure generating section; a negative pressure generating recess; and an information transducer device provided at the air outlet end. And a sloped face is further provided extending from an air outlet side of the negative pressure generating recess to at least one end of ends at the air outlet end, the disk inner edge side, and the disk outer edge, and being arranged such that a distance of the sloped face from the disk becomes gradually larger toward the ends. Another configuration of the head slider of the invention includes an opposing face opposing a disk; an air inlet end; an air outlet end; a disk inner edge side; and a disk outer edge side. The opposing face opposing the disk includes: a positive pressure generating section; a negative pressure generating recess; and an information transducer device provided at the air outlet end section. And a through hole is further provided extending from the negative pressure generating recess to an end face at the disk inner edge side or an end face at the disk outer edge side.

[0014]

According to the above-described configuration, the negative pressure generated in high-speed unloading can be decreased quickly, and damage of the suspension is prevented and the lifting stroke can be reduced so that a thinner type of disk recording and playing back apparatus can be

realized.

[0015]

And the other configuration of the invention is as follows. A first air-bearing face and a second air-bearing face are provided. The first air-bearing face includes a positive pressure generating section, a negative pressure generating recess, and an information transducer device. The second air-bearing face is slanted to the first air-bearing face by a predetermined angle.

[0016]

According to the above described configuration, a high speed unloading and a stable flying operation becomes possible as the head slider does not touch the disk surface eve if the suspension vibrates when loading, hence a high density recording and a thinner type of disk recording and playing back apparatus can be realized

[0017]

[Embodiments of the Invention]

A head slider described in claim 1 includes an opposing face opposing a disk; an air inlet end; an air outlet end; a disk inner edge side; and a disk outer edge side. The opposing face includes: a positive pressure generating section; a negative pressure generating recess; an information transducer device disposed at the air outlet end; and a sloped face. The sloped face extends from an end section near an air outlet side of the negative pressure generating recess to at least one end of ends at the air outlet end, the disk inner edge side, and the disk outer edge side, and being arranged such that a distance from the disk is gradually larger toward the ends while the head slider opposing the disk. According to the above-described configuration, the negative pressure generated when lifting the head slider vertically can be reduced quickly and a high speed loading/unloading on the NCSS system can be realized, therefore a high density recording and playing back apparatus can be provided.

[0018]

A head slider described in claim 2 includes an opposing face opposing a disk; an air inlet end; an air outlet end; a disk inner edge side; and a disk outer edge side. The opposing face opposing the disk includes: a positive pressure generating section; a negative pressure generating recess; an information transducer device disposed at the air outlet end; and a through hole extending from the negative pressure generating recess to an end face at the disk inner edge side or an end face at the disk outer edge side. According to the above configuration, the negative pressure can be decreased quickly if the head slider is moved parallel to the disk at a high speed. Thus the head slider can be moved to a retreat position by lifting the head slider from any position over the disk surface and a suitable NCSS system can be adopted according to each disk recording and playing back apparatus.

[0019]

In the head slider described in claim 3 the opposing face opposing the disk includes two air-bearing faces, the two air-bearing faces include a first air-bearing face and a second air-bearing face. The first air-bearing face includes: a positive pressure generating section; a negative pressure generating recess; and an information transducer device disposed at the air outlet end. The second air-bearing face includes: a sloped face extending from the end section near an air outlet side of the negative pressure generating recess to at least one end of ends at the air outlet end, the disk inner edge side, and the disk outer edge side, and the sloped face is arranged such that a distance from the disk is gradually larger toward the ends while the head slider opposing the disk. According to the above configuration, the negative pressure generated when the head slider is lifted vertically can be decreased quickly. Even if vibration of the suspension at the time of loading is generated, the head slider does not touch the disk and hence stable loading is realized. And a stable recording and playing back operation is realized because a floating attitude can be maintained due to one of the two air-bearing faces even when subjected to external

disturbance while steadily floating over the disk surface. Therefore the disk recording and playing back apparatus resistant to impulse and of high recording density on the NCSS system can be realized.

[0020]

In the head slider described in claim 4, the positive pressure generating section including: two side rails disposed at a predetermined distance from each end of ends at the disk inner edge side and the disk outer edge side so as to be extended from the air inlet end towards the air outlet end; and a cross rail disposed at a predetermined distance from the air inlet end and arranged perpendicularly to the air inflow direction and connected with the two side rails. The negative pressure generating recess including: a lower-leveled face surrounded by the positive pressure generating section and a flotation improving face formed in a central portion at the air outlet end, separately from the positive pressure generating section. According to the above configuration, the flying height can be stabilized while steadily floating, and an effect of the negative pressure decrease is improved due to air inflow from the sloped face or the through hole while unloading.

[0021]

In the head slider described in claim 5, the sloped face is a tapered face extending from the end section near an air outlet side of the negative pressure generating recess to the air outlet end such that a distance from the disk is gradually larger while the head slider opposing the disk. According to the above structure, the air comes easily in the negative pressure generating recess in unloading and the negative pressure decreases quickly. High precision surface profile by a simple processing can be realized and the second air-bearing face can be processed according to a predetermined design.

[0022]

In the head slider described in claim 6, the sloped face is a curved face extending from the end section near the air outlet side of the negative

pressure generating recess to at least one end of ends at the air outlet end, the disk inner edge side, and the disk outer edge side, and the curved face is arranged such that a distance thereof from the disk changes continuously larger toward the ends while the head slider opposing the disk. According to the above configuration, the air comes easily in the negative pressure generating recess in unloading and the negative pressure decreases quickly. If the sloped face is the second air-bearing face, flying attitude can be controlled even when the roll angle varies due to shock in loading and steady flying, and thus further stable loading operation and steady flying can be realized.

[0023]

A head slider described in claim 7 includes e a disk serving as a recording medium; a driver for rotationally driving the disk; a suspension capable of swinging and having a head slider attached to a tip of the suspension facing the disk; and a retreat position where the head slider is held retreated when the disk is stopped. The head slider includes an opposing face opposing the disk ; an air inlet end; an air outlet end; a disk inner edge side; and a disk outer edge side. The opposing face includes: a positive pressure generating section; a negative pressure generating recess; an information transducer device disposed at the air outlet end ; and a sloped face extending from an end section near an air outlet side of the negative pressure generating recess to at least one end of ends at the air outlet end, the disk inner edge side, and the disk outer edge side, and being arranged such that a distance from the disk is gradually larger toward the ends while the head slider opposing the disk. According to the above structure, a high density disk recording and playing back apparatus with a small flying height can be realized.

[0024]

A head slider described in claim 8 includes a disk serving as a recording medium; a driver for rotationally driving the disk; a suspension capable of swinging and having a head slider attached to a tip of the suspension such that the head slider faces the disk; and a retreat position

where the head slider is held retreated when the disk is stopped. The head slider includes: an opposing face opposing a disk; an air inlet end; an air outlet end; a disk inner edge side; and a disk outer edge side. The opposing face includes: a positive pressure generating section; a negative pressure generating recess; an information transducer device disposed at the air outlet end; and a through hole extending from the negative pressure generating recess to an end face at the disk inner edge side or an end face at the disk outer edge side. According to the above configuration, a disk recording and playing back apparatus can perform an operation of unloading of lifting the head slider while the head slider is moving parallel to the disk surface at a high speed, therefore the apparatus is capable of unloading operation from any position over the disk.

[0025]

Exemplary embodiments of the present invention will be described below with reference to the accompanying drawings.

[0026]

(First embodiment)

Figs. 1A and 1B show a sectional view along a line A-B-C-D of a plan view and the plan view of the head slider seen from a side of its face opposing a disk of the head slider of the first embodiment of the present invention. The head slider 100 of the first embodiment of the present invention is for using in a disk recording and playing back apparatus of on the NCSS system, for example for using in the disk recording and playing back apparatus of a ramp load type shown in Fig. 10.

[0027]

Head slider 100 includes: opposing face 30 opposing a disk; air inlet end 31 opposing the direction of disk rotation; air outlet end 32 on the opposite side; disk inner edge side 33 on the side of the disk inner side; and disk outer edge side 34 on the opposite side. The opposing face 30 includes: positive pressure generating section 35; flotation improving face

36; positive pressure improving intermediate-leveled face 37 surrounded by positive pressure generating section 35 and air inlet end 31; lower-leveled face 38 having the largest step comparing these; and sloped face 40 extended from an end on an air outlet end side of lower-leveled face 38.

[0028]

Positive pressure generating section 35 is U-shaped and includes two side rails 351 and cross rail 352 connected to these side rails. Side rails 351 are arranged in the direction from air inlet end 31 toward air outlet end 32 and in a predetermined distance apart from disk inner edge side 33 and disk outer edge side 34. Cross rail 352 is formed of an orthogonal portion located at a predetermined distance from air inlet end 31 and arranged orthogonally to the direction of the air inflow and oblique portions having both ends thereof connected to each of side rails 351.

[0029]

Flotation improving face 36 is formed in the central portion of a width from disk inner edge side 33 to disk outer edge side 34, so as to form such a hexagon as shown in Fig. 1B. Flotation improving face 36 includes positive pressure improving face 361 at the same level as positive pressure generating section 35 and an outlet side intermediate-leveled face 362 at the same level as positive pressure improving intermediate-leveled face 37. Incidentally, positive pressure improving face 361 on the side of air outlet end 32 of flotation improving face 36 has information transducer device 50 for recording and playing back information to and from the disk.

[0030]

Lower-leveled face 38 is formed of side lower-leveled faces 381 and negative pressure generating recess 382. Side lower-leveled faces 381 are provided at each position of disk inner edge side 33 and disk outer edge side 34 extended in a direction from air inlet end 31 toward air outlet end 32. Negative pressure generating recess 382 is surrounded by positive pressure generating section 35, flotation improving face 36, and sloped face 40.

[0031]

Sloped face 40 is formed from an end section near the air outlet side of negative pressure generating recess 382 to air outlet end 32 and it is tapered such that its distance from the disk in a situation opposing the disk becomes gradually larger toward the air outlet end of sloped face 40.

[0032]

Although such a head slider can be processed by die forming or by general machining, more preferable processing is application of processing technology not only wet or dry etching but also laser beam irradiation or ion irradiation.

[0033]

In the first embodiment the method of processing by means of ion irradiation is used to set the difference in level between positive pressure generating section 35 and positive pressure improving intermediate-leveled face 37 to 0.08 μm and the difference in level between positive pressure improving intermediate-leveled face 37 and lower-leveled face 38 to 1.2 μm. The angle between sloped face 40 and lower-leveled face 38 is set to 0.6 mrad and the length of sloped face 40 is set to 0.15 mm. As to the overall size of head slider 100, the dimension in the longitudinal direction from the air inlet end to the air outlet end, the dimension in the lateral direction from the disk inner edge side to the disk outer edge side, and the thickness are set to 1 mm, 0.7 mm, and 0.23 mm, respectively.

[0034]

To compare head slider 100 as to effects with a comparison example, head slider 500 provided with no sloped face was produced as shown in Figs. 12A and 12B. Although overall size of head slider 500 is the same as that of head slider 100, lower-leveled face 38 is extended to air outlet end 32. The components with the same function and the same name corresponding to the embodiment shown in Figs. 1A and 1B are denoted by the same reference numerals, and the description will be omitted.

Lower-leveled face 38 includes side lower-leveled faces 381, negative pressure generating recess 382, and outlet side lower-leveled face 383. Through comparison of head slider 100 with head slider 500, the present invention will be described.

[0035]

Figs. 2A and 3A are sectional views of the respective head sliders while being steadily afloat over rotating disk 2, Fig. 2A shows the case of head slider 100 of the first embodiment and Fig. 3A shows the case of head slider 500 for comparison. Head slider 100 and head slider 500 are each supported by a suspension through a gimbal so as to be given a load to be pressed against disk 2 through a pivot at the tip of the suspension. Since the supporting structure itself is the same as was shown in Fig. 10, it is omitted in the present drawings. The air flow occurring due to the rotation of disk 2 flows in the direction indicated by arrow U. Referring to Fig. 2A, when the air flow flows into positive pressure generating section 35, it is compressed at this section, especially in the gap between cross rail 352 and disk 2, whereby a positive pressure to lift up head slider 100 is generated. After passing by cross rail 352, the air flow is abruptly expanded at negative pressure generating recess 382 having a deep step and hence a negative pressure to attract head slider 100 toward disk 2 is generated. By an equilibrium of the load from the suspension, force of positive pressure, and force of negative pressure, head slider 100 flies afloat steadily in an attitude with a side of air inlet end 31 slightly opened from the surface of disk 2. When head slider 100 of the first embodiment is making steady floatation, point of applications of the load and the forces and angle of the sloped face are so designed that SHL < SHT is satisfied, where SHL and SHT are the distances of the positions of end E on the air inlet side and end F on the air outlet side of sloped face 40, respectively, from disk 2.

[0036]

Since the state making steady fly of head slider 500 of the comparison example shown in Fig. 3A is the same as that described with reference to Fig. 2A, the description will be omitted.

[0037]

Results of analysis of pressure distribution in head slider 100 of the first embodiment and head slider 500 without the sloped face of the comparison example while steadily flying are shown in Figs. 2B and 3B. The pressure distribution shown in each drawing is a result obtained as an analysis at four positions in the lateral direction of the head slider and along the longitudinal direction from air inlet end to air outlet end. The pressure distribution is obtained at the same positions for head slider 100 of the present embodiment and head slider 500 for comparison. Reference characters J and I in the drawings are given for ease of understanding the connection between the generated pressures and the relative positions in the head slider.

「0038」

In a steady flying there is observed no great difference between the head sliders except that the negative pressure at the portion of sloped face 40 (between E and F) of head slider 100 is slightly smaller than that at the corresponding portion of the comparison example shown in Fig. 3B. From this, it is known that the effect of the sloped face in a steady flying is small and stabilized flying is achieved.

[0039]

Further, stability of the head sliders in a steady flying is compared with respect to the pitch angle and the roll angle. Pitch angle rigidity is defined as the rate of the pitch angle varying with an external disturbance. The angle formed between a face from disk inner edge side 33 to disk outer edge side 34 of the lateral direction of the head slider and the disk surface is called the roll angle and the rate of the roll angle varying with an external force is defined as the roll angle rigidity. Results of comparison about such rigidity are shown in Table 1. As understood from Table 1, there are not observed great differences between head slider 100 provided with sloped face 40 and head slider 500 of the comparison example, and stable flying height can be maintained.

[0040]

TABLE 1

	Head Slider of First Embodiment (gf/nm)	Head Slider of Comparison Example (gf/nm)
Pitch Angle Rigidity	0.178	0.180
Roll Angle Rigidity	0.1	0.11

[0041]

Referring to Figs. 4A, 4B, and 5, effects obtained while unloading is made will now be described. Figs. 4A and 4B show only main portions of the cross-sections along a line A-B-C-D shown in Figs. 1B and 12B. At the time of unloading in the NCSS system, the space between the head slider and the disk is abruptly expanded when the head slider is pulled upward and thereby an additional negative pressure is generated. The negative pressure has such a characteristic that it becomes larger according as the vertically moving speed for unloading is greater.

[0042]

In the case of head slider 500 of the comparison example shown in Fig 4B, when load Fs from the suspension (not shown) is decreased for performing unloading, the distance between disk 2 and head slider 500 becomes larger. With the increase in this distance, positive pressure Fp decreases linearly. However, since there occurs an increase in the negative pressure due to sudden expansion of the space, negative pressure Fn decreases delayed from decrease of positive pressure. In the case of head slider 100 of the first embodiment shown in Fig. 4A, the points of application of each load and the angle of the sloped face are designed such that the distance of positions of end E on the air inlet end side and end F on the air outlet end side of sloped face 40, respectively, from the disk face is given by SHL < SHT. According as load Fs from the suspension (not

shown) is decreased for performing unloading, the distance between disk 2 and head slider 100 becomes larger. With the increase in this distance, positive pressure Fp decreases linearly. At the same time, since the distance between air outlet end side F of sloped face 40 and disk 2 is made larger, an inflow of air indicated by arrow G is introduced from the side of air outlet end 32 into negative pressure generating recess 382. Negative pressure Fn of head slider 100 of the first embodiment quickly decreases comparing to head slider 500 of the comparison example shown in Fig. 4B.

[0043]

On negative pressure suppression effect by inflow of air, results of analysis of the generated negative pressure versus the vertically moving speed of the head slider at the time it is lifted up are shown in Fig. 5. Degree of increase of the negative pressure of head slider 100 of the first embodiment is smaller than that of head slider 500 of the comparison example even if the vertically moving speed is increased. Therefore, the vertically moving speed at the time of unloading can be made greater and high-speed unloading can be achieved.

[0044]

As described above, head slider 100 of the first embodiment can secure a certain amount of negative pressure while it is steadily afloat over disk 2, and, at the time of unloading, negative pressure can be quickly decreased by virtue of the air inflow from sloped face 40. Hence, unloading operation can be performed quickly. Further, because of the quick decrease of the negative pressure during the unloading operation, it is not required to exert a large force to lift the suspension. Further the stroke for lifting the suspension can be decreased and, hence, it becomes possible to produce a thinner type of disk recording and playing back apparatus.

[0045]

In the head slider of the first embodiment, the point of application of the negative pressure can also be set closer to the air inlet side than are the point of application of the load from the suspension and the point of

application of the positive pressure. By virtue of this design, it can also be prevented that head slider collides with disk when it is caused to approach the disk by an external shock at the time of unloading and hence positive pressure increases, the angular moment acts so as to increase the distance between air outlet end and the surface of disk.

[0046]

In the first embodiment, the operation to separate the head slider from the disk is performed by rotating the actuator arm to allow the actuator arm to land on the ramp. However, a piezoelectric element or driving motor, for example, to drive the head slider in the direction vertical may be used in order to separate the head slider apart from the disk.

[0047]

Further, the head slider is not limited to that of the ramp loading type in which unloading is performed at the outer periphery portion of disk but the head slider can be separated from the surface of the disk at any position from inner periphery to outer periphery.

[0048]

In the first embodiment, the head slider has been described to be non-contact type of flying afloat over the disk surface. However, the invention is also applicable to such a case in which the head slider is substantially afloat, i.e., a portion of the head slider is very softly in touch with the disk surface.

[0049]

(Second Embodiment)

Fig. 6 is a perspective view of head slider 300 of a second embodiment of the present invention seen from a face opposing a disk. This head slider 300 has the same configuration as that of head slider 500 of the comparison example shown in Figs. 12A and 12B except that it is provided with a through hole 45 going from negative pressure generating

recess 382 to end face 341 of disk outer edge side 34. Corresponding components of the same name are denoted by corresponding reference numerals and the description will be omitted. Head slider 300 of the second embodiment has a long side of 1.2 mm, a short side of 1 mm, and a thickness of 0.3 mm. Through hole 45 has a diameter of 20 μm and goes straight from end face 341 to negative pressure generating recess 382.

[0050]

Head slider 300 of the second embodiment is also used for disk recording and playing back apparatus on the NCSS system including for example the mechanism of ramp loading type as shown in Fig. 2 or the like.

[0051]

When head slider 300 of the second embodiment is moved parallel to the disk surface toward the outer edge side of the disk, air collides with end face 341 of disk outer edge side 34 and air pressure around there rises. The pressure causes an inflow of air into negative pressure generating recess 382 via through hole 45, whereby the negative pressure is decreased. The higher the speed of the movement of head slider 300, the greater the air inflow and, hence, the greater the decrease in the negative pressure is. Accordingly, it becomes possible to lift head slider 300 upward while it is moved parallel to the disk at a high speed and, thus, an unloading operation at any position on disk 2 can be performed.

[0052]

On the other hand, the moving speed of head slider 300 when it is to be positioned at a designated track position while it is steadily afloat over disk 2 is slower than the moving speed at the time of unloading. Therefore, the inflow of air is scarcely produced and, hence, the positive pressure and negative pressure function as in head slider 500 of the comparison example so that steady floating of the head slider is secured.

[0053]

Although description has been given above as to the mechanism to

perform head slider unloading at an arbitrary disk position, it is of course possible to apply the same type of the head slider to a disk recording and playing back apparatus employing a ramp loading mechanism.

[0054]

Although the through hole is provided so as to go from end face of disk the outer edge side to the negative pressure generating recess in the present embodiment, it may be provided so as to go from the end face of the disk inner edge side to the negative pressure generating recess. Further, the through holes may be provided so as to go from both end faces to the negative pressure generating recess.

[0055]

Although lubricant or foreign matter can collect within the negative pressure generating recess due to presence of negative pressure there, such lubricant or foreign matter may be eliminated by causing air to be positively led from the through hole into the negative pressure generating recess by swinging the actuator arm quickly in the radial direction of the disk.

[0056]

Although a configuration of head slider having no sloped face provided on the side of the air outlet end is employed in the present embodiment, the invention is not limited to that configuration. Such a configuration may be used that has two air-bearing faces of a first air-bearing face and a second air-bearing face as described below: namely, the first air-bearing face is made up of a through hole going from at least one of the end faces on the disk inner edge side and disk outer edge side to the negative pressure generating recess, the negative pressure generating recess, the positive pressure generating section, and the information transducer device, while the second air-bearing face is slanted to the first air-bearing face. By virtue of this configuration, not only the unloading operation can be performed steadily, but also, even when the head slider is greatly slanted due to vibration of the suspension at the time of loading, the head slider can be kept afloat with its attitude controlled.

[0057]

(Third Embodiment)

Fig. 7A and 7B are a sectional view seen along a line A-B-C-D of head slider 400 of the third embodiment of the present invention and a plan view seen from its face opposing a disk, respectively. This head slider 400 is also used in a disk recording and playing back apparatus on the NCSS system. For example, it may be used in the disk recording and playing back apparatus using a ramp loading mechanism as shown in Fig. 10. Head slider 400 of the third embodiment of the present invention has a face opposite a disk which face includes two air-bearing faces, i.e., a first air-bearing face 60 and a second air-bearing face 65.

[0058]

First air-bearing face 60 includes positive pressure generating section 35, flotation improving face 36, positive pressure improving intermediate-leveled face 37, lower-leveled face 38, and an information transducer device 50 provided on the downstream side of positive pressure improving face 361. Second air-bearing face 65 is constituted of a sloped face extending from an end on an air outlet side of lower-leveled face 38 to air outlet end 32 and having virtually the same area as first air-bearing face 60. Further, the angle formed between first air-bearing face 60 and second air-bearing face 65 is set at 0.9 mrad. The other shapes are the same as that of the first embodiment. The elements of Figs. 1A and 1B having the same name are assigned the same reference numerals.

[0059]

Operation of head slider 400 of the present embodiment will be described below. A sectional view of head slider 400 steadily afloat over disk 2 is shown in Fig. 8A. An air flow occurring with the rotation of disk 2 flows in the direction indicated by arrow U. As this air flow enters the space along first air-bearing face 60, the air flow is compressed at the section of cross rail 352 and a positive pressure is generated by the effect of viscosity. When the air flow reaches the section of negative pressure generating

recess 382, a negative pressure is generated because the space there suddenly expands, as was the case in head slider 100 of the first embodiment of the invention. Meanwhile, in this state, either negative pressure or positive pressure is scarcely produced at the section along second air-bearing face 65 because it is further apart from the surface of disk 2 than is negative pressure generating recess 382 of first air-bearing face 60. Results of analysis of pressure distribution in such a state are shown in Fig. 8B. Reference characters J, Q, and R in Figs. 8A and 8B are given for ease of understanding the connection between the generated pressures and the relative positions in the head slider. As seen from the drawings, although positive pressures and negative pressures are generated at the section along first air-bearing face 60, only slight negative pressures are generated at the air inlet end side of the second air-bearing face 65. The positive pressures and the negative pressures being generated at first air-bearing face 60 are virtually equal to those in the case of head slider 100 of the first embodiment shown in Fig. 2B and the effect produced by second air-bearing face 65 is very little. Accordingly, the floating characteristic at the time of steady floating is such that the attitude of head slider 400 is controlled by first air-bearing face 60.

[0060]

Next the case at the time of unloading operation will now be explained. When the load from the suspension is decreased for unloading, the positive pressure decreases immediately. Since an air inflow is produced from air outlet end 32 to negative pressure generating recess 382, the negative pressure also decreases almost at the same time as the positive pressure decreases. This is the same as the case with head slider 100 of the first embodiment.

[0061]

Further, even when the head slider is loaded over the disk surface in its state having a large pitch angle due to vibration from the suspension, a steady loading can be performed. Fig. 9A shows the relationship between head slider 400 and disk 2 when a loading operation is performed with the

head slider at a large pitch angle. When the pitch angle is transiently increased as in this case, second air-bearing face 65 comes close to disk 2 to decrease its distance from the disk, thereby compressing air and generating a positive pressure due to the effect of viscosity. Results of analysis of pressure distribution at this time are shown in Fig. 9B. Reference characters J, Q, and R in Fig. 9A and 9B are given for ease of understanding the connection between generated pressures and the relative positions in the head slider. As seen from the drawings, although virtually neither positive pressures nor negative pressures are generated at first air-bearing face 60, great positive pressures are generated at second air-bearing face 65. By virtue of the positive pressure generated at second air-bearing face 65, head slider 400 is prevented from contacting disk 2 and allowed to be loaded with a certain flying height.

[0062]

When the pitch angle is small, first air-bearing face 60 operates in the same manner, in head slider 400 of the present embodiment, stable loading can be performed even if the pitch angle varies at the time of loading.

[0063]

Head slider 400 of the present embodiment can provide enhanced stability at the time of loading/unloading. Moreover even when an external impulse is given to the head slider to vary the attitude of the head slider, a restoring force functions and therefore a disk recording and playing back apparatus which is resistant to impulse and reliable can be realized.

[0064]

In head slider 400 of the present embodiment, the second air-bearing face is stated to be a flat sloped face extending to air outlet end. However, it may be a sloped face extending to at least one of the disk inner edge side and the disk outer edge side. Otherwise, it may be a curved sloped face extending to at least one of the ends at the air outlet end, the disk inner edge side, and the disk outer edge side.

[0065]

Although the angle formed between first air-bearing face 60 and second air-bearing face 65 of the present embodiment is stated to be 0.9 mrad, the present invention is not limited to it. Design of the angle may be suitably changed within a range of angle larger than the pitch angle of the head slider with respect to the disk while it is steadily floating over the disk surface and smaller than the pitch angle produced by vibration of the suspension at the time of loading. Since, generally, the pitch angle during the steady state is from 0.05 mrad to 0.1 mrad and pitch angle produced at the time of loading is from 1 mrad to 2 mrad, a range from 0.05 mrad to 2 mrad may preferably, or a range from 0.1 mrad to 1 mrad may more preferably, be selected as the more preferable range of the angle.

[0066]

Further, in the head slider of the third embodiment, the size of the second air-bearing face is stated to be virtually equal to that of the first air-bearing face. However, the invention is not limited to that size ratio. The size ratio between the second air-bearing face and the first air-bearing face allowing the second air-bearing face to fully exhibit its performance may be within a range of 1 to 0.05 - 1.0. However, if enhancement of stability at the time of loading, as well as allowance in designing, is considered, a ratio of 1 to 0.5 - 1.0 may be selected as a further preferable range.

[0067]

Although, in the first to third embodiments of the present invention, head sliders with a flotation improving face provided at the air outlet end have been described, the invention is not limited to the described configuration. For example, such a head slider may be used which has no flotation improving face provided but has the side rails on both sides further extending toward the side of the air outlet end and has an information transducer device provided at the outlet end of one of the side rails. Further, such a configuration may be made in which the positive pressure improving intermediate-leveled face of the head slider is modified to have a

taper so that a distance from the disk becomes gradually larger toward the air inlet end while opposing the disk. Thus, suitable designing may be made for the positive pressure generating section and the negative pressure generating recess.

[0068]

[Effect of the Invention]

As described above the invention realizes a stable low flying height on the NCSS system and provides a high density disk recording and playing back apparatus by providing a sloped face extending from the negative pressure generating recess to the air outlet end so that a distance from the disk surface becomes gradually larger toward the air outlet end while the head slider opposing the disk. Because the negative pressure in unloading can be decreased quickly, damage of the suspension is prevented and thinner type of disk recording and playing back apparatus is realized.

[0069]

Unload mechanism on the NCSS system for unloading the head slider while moving the head slider in a parallel direction to the disk surface at a high speed is realized by providing the through hole extending from the negative pressure generating recess to an end face at the disk inner edge side or an end face at the disk outer edge side. Thus a smaller and thinner loading/unloading mechanism capable of high density recording can be realized.

[0070]

Loading/unloading operation on the NCSS system can be made more stable by providing a first air-bearing face and a second air-bearing face of the head slider, the first air-bearing face including a positive pressure generating section, a negative pressure generating recess, and an information transducer device, the second air-bearing face is slanted to the first air-bearing face by a predetermined angle. Moreover stable flying height is realized in a steady operation. Therefore a disk recording and

playing back apparatus for high density recording and mountable on an apparatus with external shock etc. can be realized with a smaller and thinner loading/unloading mechanism.

[BRIEF EXPLANATION OF THE DRAWINGS]

Fig. 1A is a cross-sectional view of a head slider along a line A-B-C-D of a plan view according to the first embodiment of the invention.

Fig. 1B is a plan view of the head slider seen from the side of its face opposing a disk.

Fig. 2A is a cross-sectional view of the head slider of the first embodiment of the invention while the same is steadily afloat over a disk.

Fig. 2B is a pressure distribution graph of the head slider while the same is steadily afloat over a disk.

Fig. 3A is a cross-sectional view of the head slider for comparison while the same is steadily afloat over a disk.

Fig. 3B is a pressure distribution graph of the head slider while the same is steadily afloat over a disk.

Fig. 4A is a drawing showing loads and air flows of the head slider of the first embodiment of the invention while the same is pulled upward from the surface of a disk.

Fig. 4B is a drawing showing loads and air flows of the head slider for comparison while the same is pulled upward from the surface of a disk.

Fig. 5 is a graph showing relationship between the vertical moving speed when head sliders are vertically pulled upward and related negative pressures.

Fig. 6 is a perspective view of a head slider according to a second embodiment of the invention seen from the side of its face opposing a disk.

Fig. 7A is a cross-sectional view along a line A-B-C-D line of a plan view of a head slider according to a third embodiment of the invention.

Fig. 7B is a plan view of the head slider seen from the side of its face opposing a disk.

Fig. 8A is a cross-sectional view of the head slider according to the third embodiment of the invention while the same is steadily afloat over a disk.

Fig. 8B is a pressure distribution graph of the head slider according to the third embodiment of the invention while the same is steadily afloat over a disk.

Fig. 9A is a cross-sectional view of the head slider according to the third embodiment of the invention when the same is loaded over the disk.

Fig. 9B is a pressure distribution graph of the head slider according to the third embodiment of the invention when the same is loaded over a disk.

Fig. 10 is a perspective view of a disk recording and playing back apparatus of a ramp loading type using a conventional head slider and a head slider of the invention.

Fig. 11A is a plan view of a conventional head slider of the ramp loading type seen from the side of its face opposing a disk.

Fig. 112B is a cross-sectional view of the conventional head slider while the same is afloat over a disk.

Fig. 12A is a cross-sectional view along a line A-B-C-D of a plan view of a head slider produced for comparison with the head slider of the embodiment of the invention.

Fig. 12B is a plan view of the head slider seen from the side of its face opposing a disk, produced for comparison with the head slider of the embodiment of the invention.

[Explanation of the reference numerals]

1 main shaft

2	disk
3	head slider
4	driver
5	actuator arm
6	voice coil motor
7	actuator shaft
8	retreat position
9	tab for loading
10	suspension
30	opposing face
31	air inlet end
32	air outlet end
33	disk inner edge side
34	disk outer edge side
35	positive pressure generating section
36	flotation improving face
37	positive pressure improving intermediate-leveled face
38	lower-leveled face
40	sloped face
45	through hole
50	information transducer device
60	first air-bearing face
65	second air-bearing face

71	closer-to-disk faces
72	both sides
73	positive pressure generating section
73a	shallow-stepped portion
73b	inlet-side closer-to-disk face
74	negative pressure generating section
76	setting region
80	information transducer device
341	end face on disk inner edge side
351	side rails
352	cross rail
361	positive pressure improving face
362	outlet side intermediate-leveled face
381	side lower-leveled faces
382	negative pressure generating recess
383	outlet side lower-leveled face

[Document Name] Abstract

[Abstract]

[Problems] To provide a head slider capable of a high speed loading/unloading operation, capable of eliminating occurrence of a contact between the head slider and a disk and securing a stable pitch-angle rigidity even when subjected to external disturbance such as an impact, thereby enabling high speed loading/unloading operations, for use in the NCSS system in which the head slider is retreated and kept in a retreat position apart from the disk surface.

[Solving Means]

A head slider (100) having, on its opposing face (30) opposing a disk, a positive pressure generating section (35), a negative pressure generating recess (382), and an information transducer device (50) provided at an air outlet end, in addition, a sloped face (40) is provided. The sloped face (40) extends from an air outlet side of the negative pressure generating recess (382) to at least one of ends at the air outlet end (32), the disk inner edge side (33), and the disk outer edge side (34), and arranged such that a distance from the sloped face (40) to the disk becomes gradually larger toward the end. According to the configuration, the negative pressure generated with high-speed unloading operation of the head slider can be decreased quickly. Therefore, a disk recording and playing back apparatus capable of eliminating damage of suspension and thinner type of disk recording and playing back apparatus can be realized.

[Selected Drawing] Fig. 1

FIG. 1A

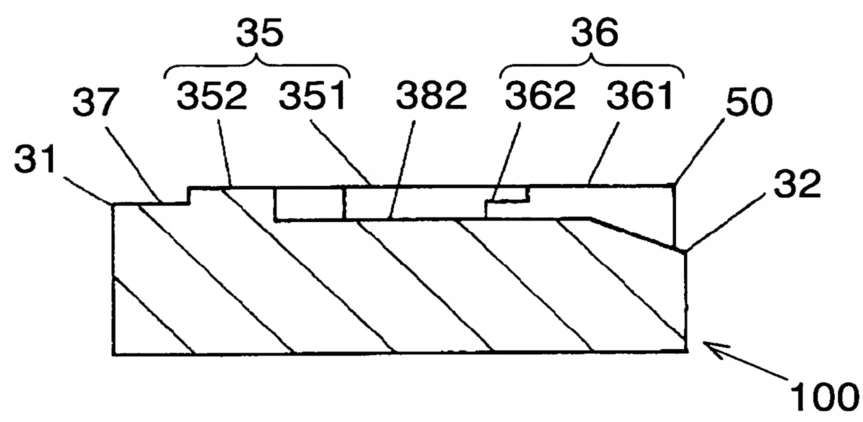

35
36
37
352
351
382
362
361
50
31
32
100

FIG. 1B

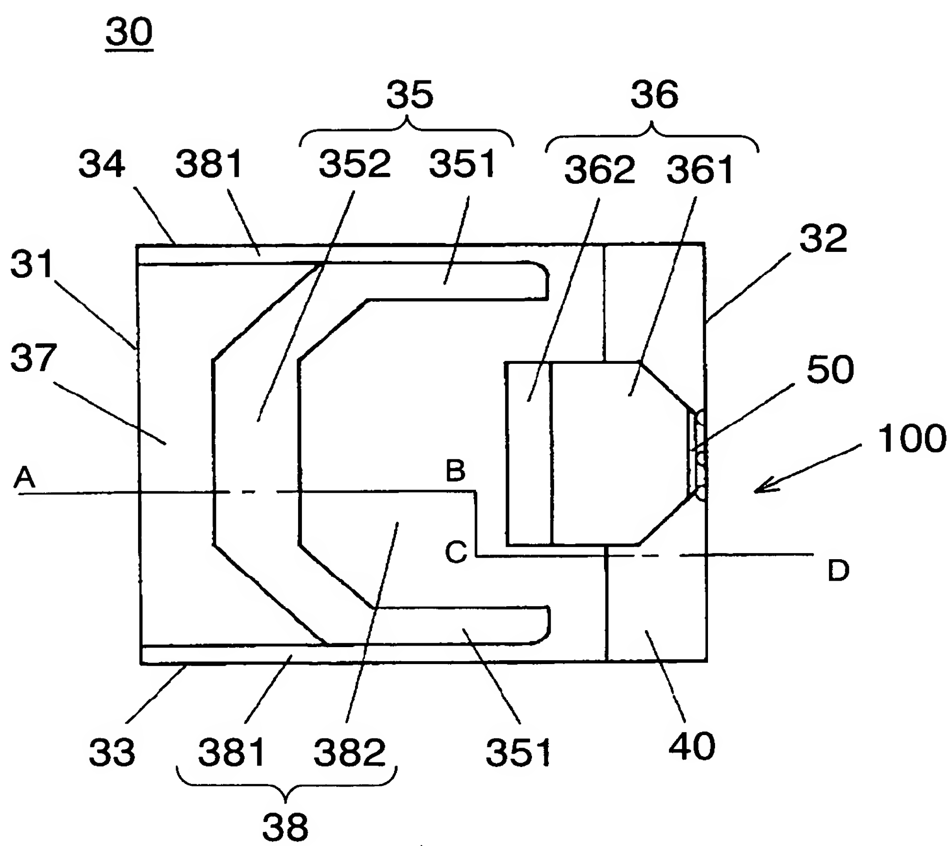

30
35
36
34
381
352
351
362
361
32
31
37
50
100
A
B
C
D
33
381
382
351
40
38

FIG. 2A

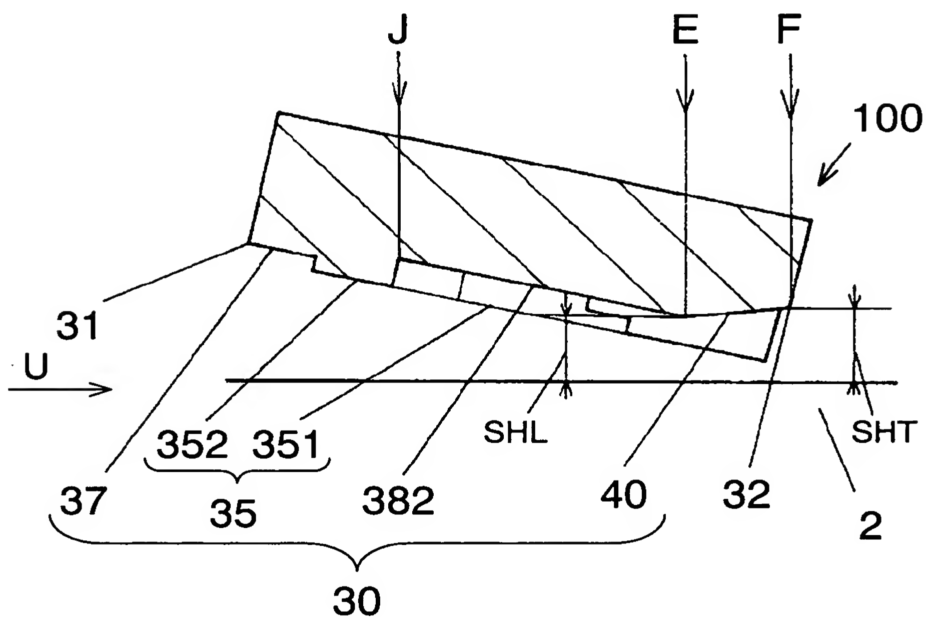

J
E
F
100
31
U
352 351
35
37
382
SHL
40
32
SHT
2
30

FIG. 2B

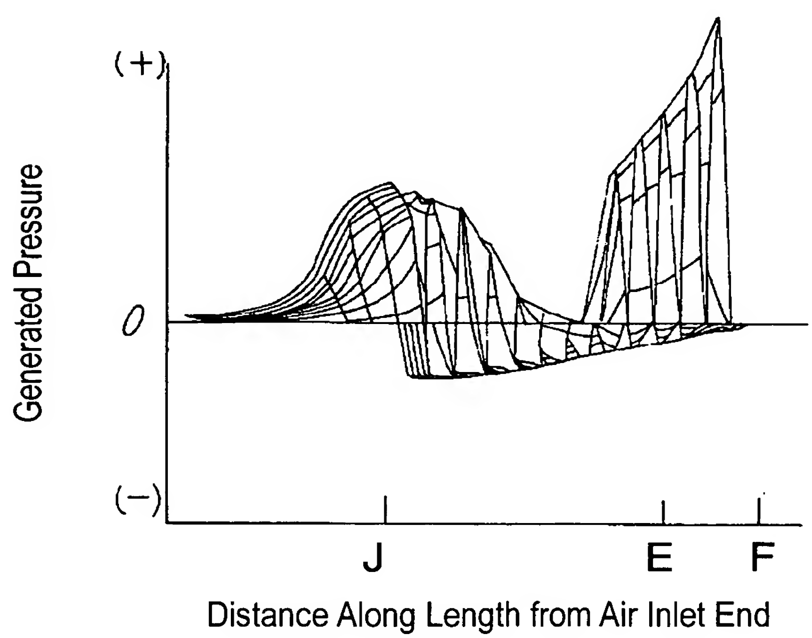

(+)
Generated Pressure
0
(−)
J
E
F
Distance Along Length from Air Inlet End

FIG.3

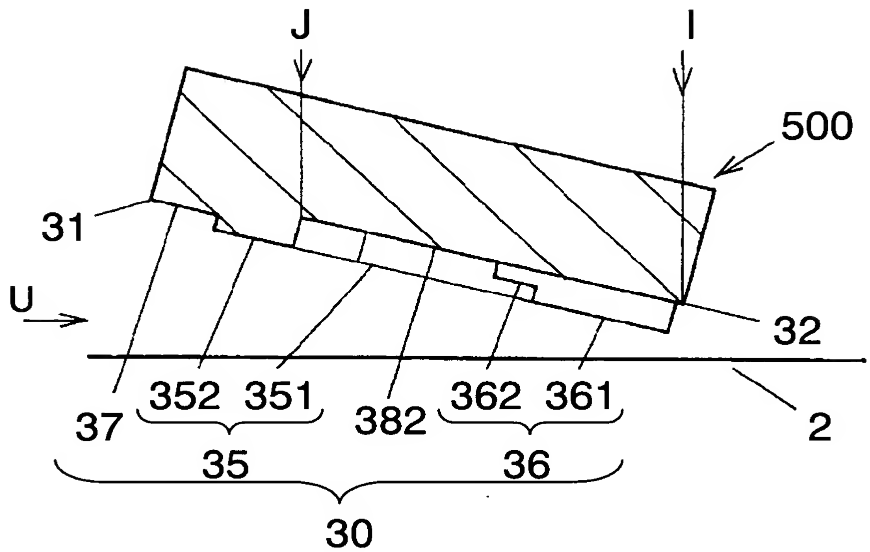

J
I
500
31
U
32
2
352
351
382
362
361
37
35
36
30

FIG.3

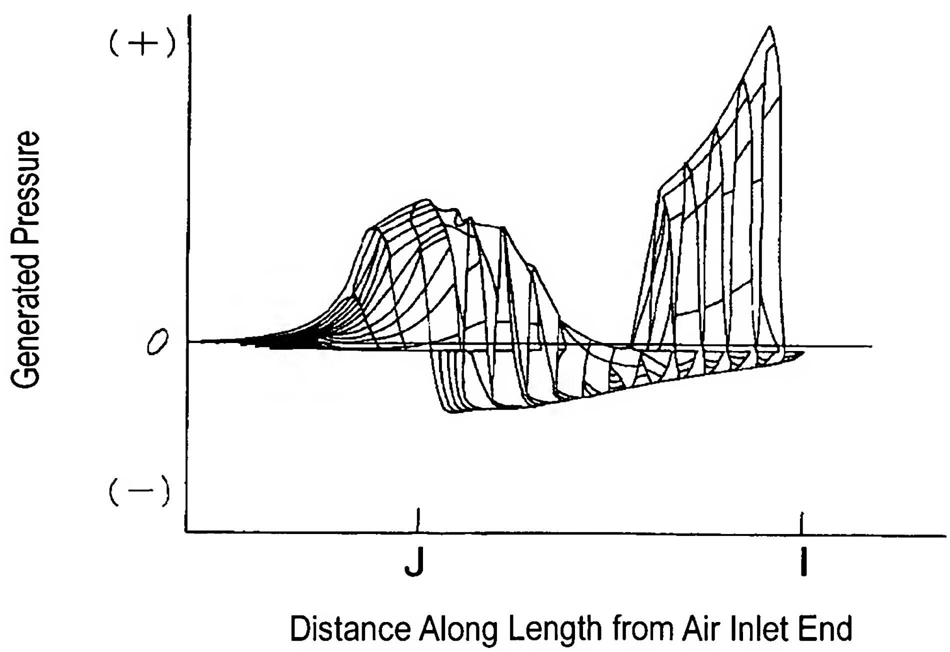

(+)
0
(−)
Generated Pressure
J
I
Distance Along Length from Air Inlet End

FIG. 4A

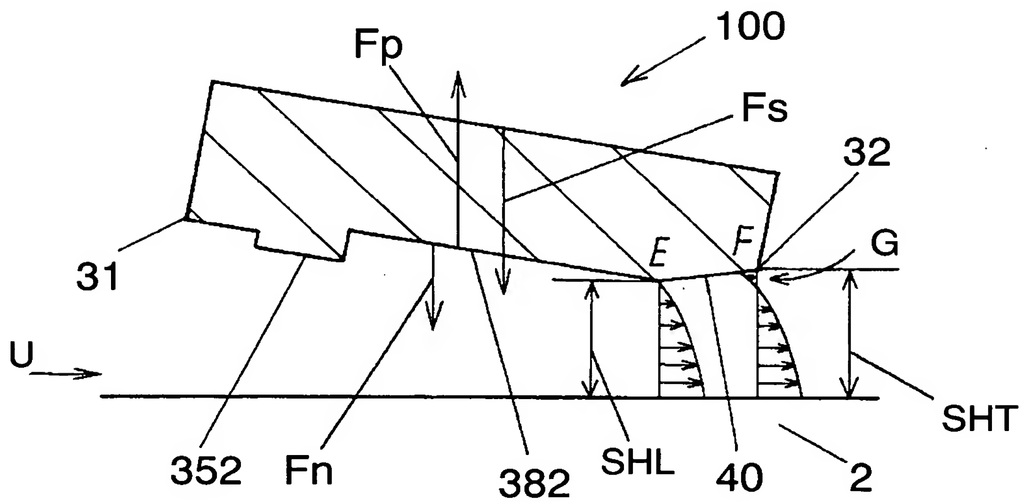

100
Fp
Fs
32
G
E
F
31
U
SHT
352
Fn
382
SHL
40
2

FIG. 4B

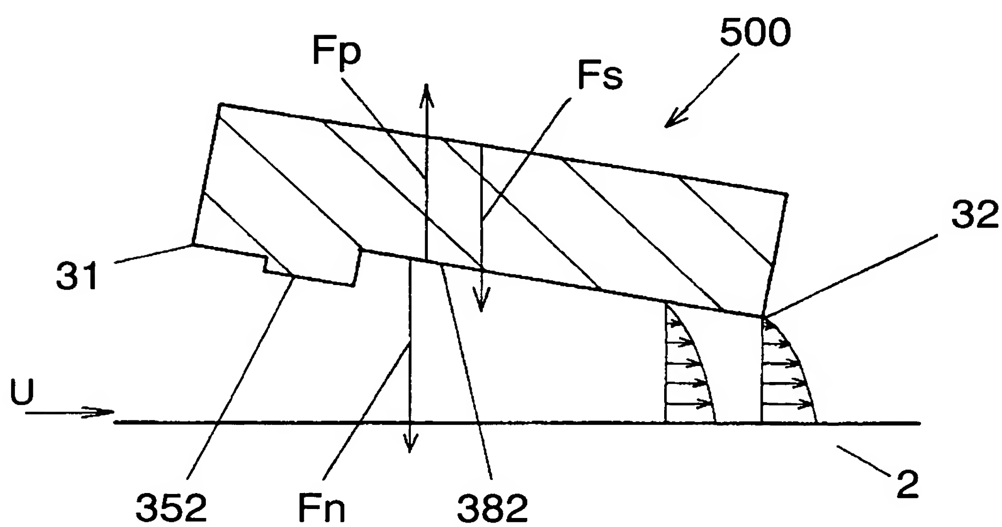

500
Fp
Fs
32
31
U
352
Fn
382
2

FIG.5

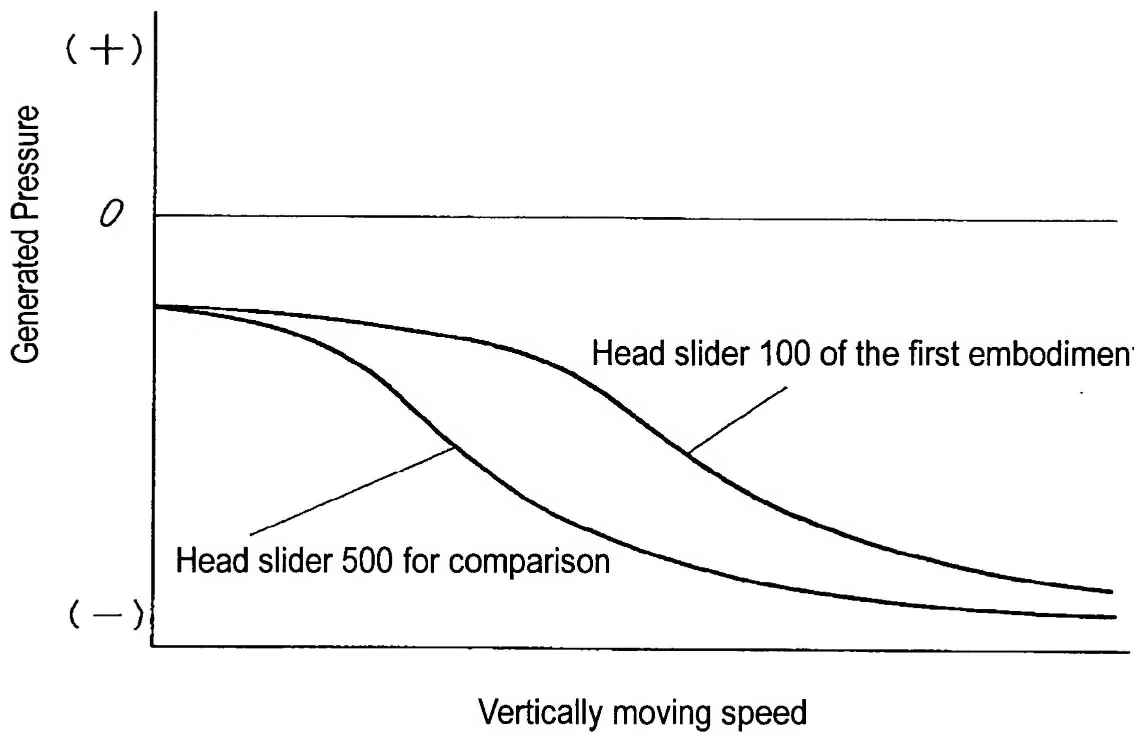

(+)
0
(−)
Generated Pressure
Head slider 100 of the first embodiment
Head slider 500 for comparison
Vertically moving speed

FIG. 6

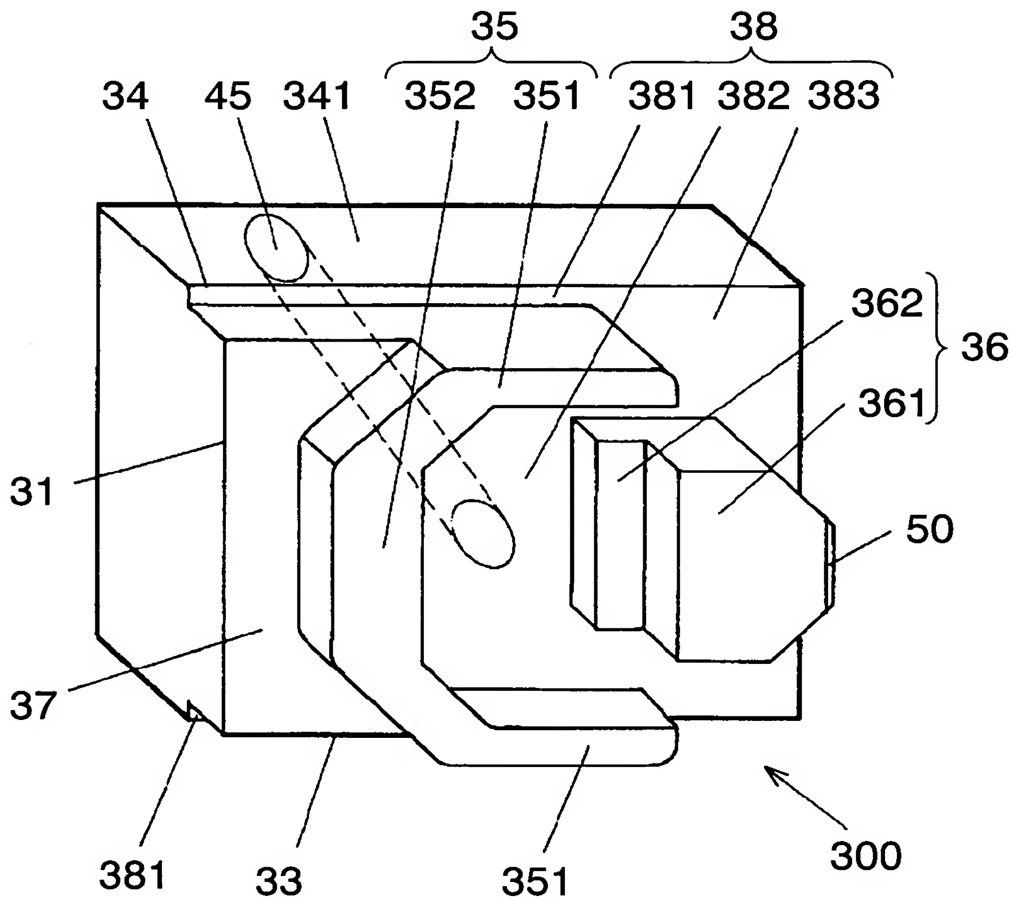
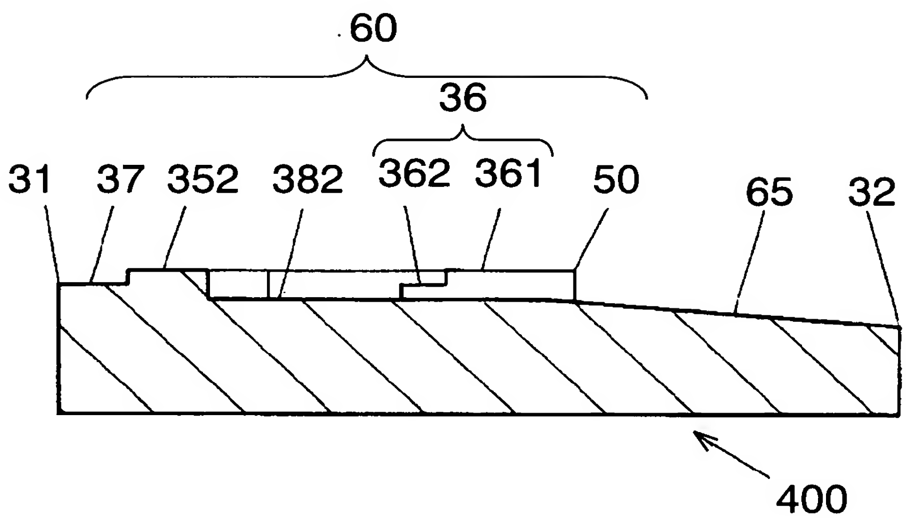
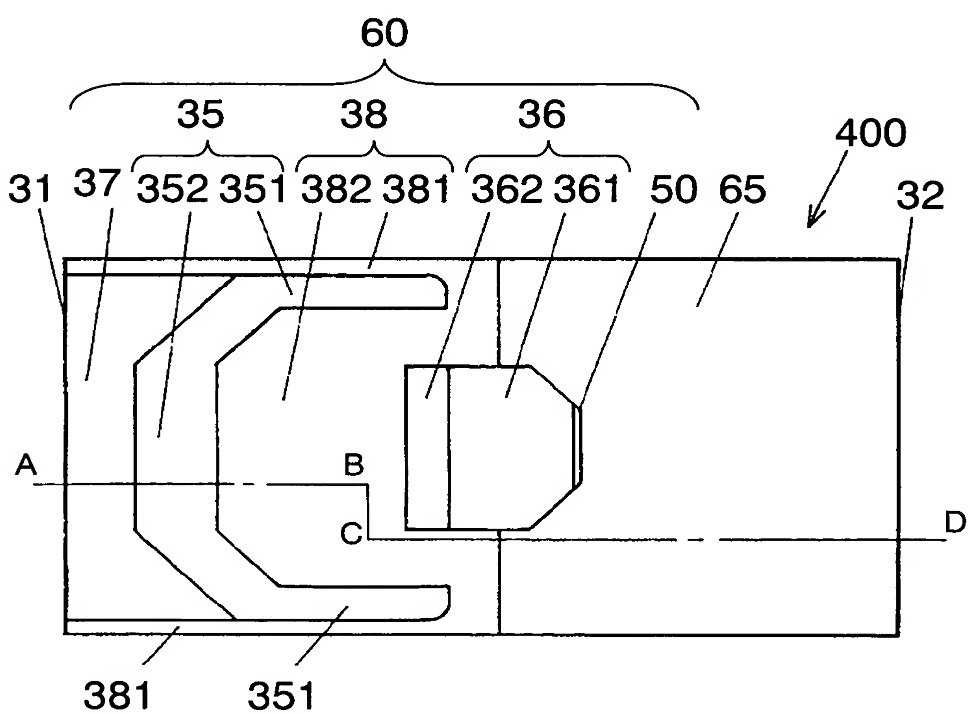

35
38
34
45
341
352
351
381
382
383
362
36
361
31
50
37
381
33
351
300

FIG. 7A



60
36
31
37
352
382
362
361
50
65
32
400

FIG. 7B



60
35
38
36
400
31
37
352
351
382
381
362
361
50
65
32
A
B
C
D
381
351

FIG. 8A

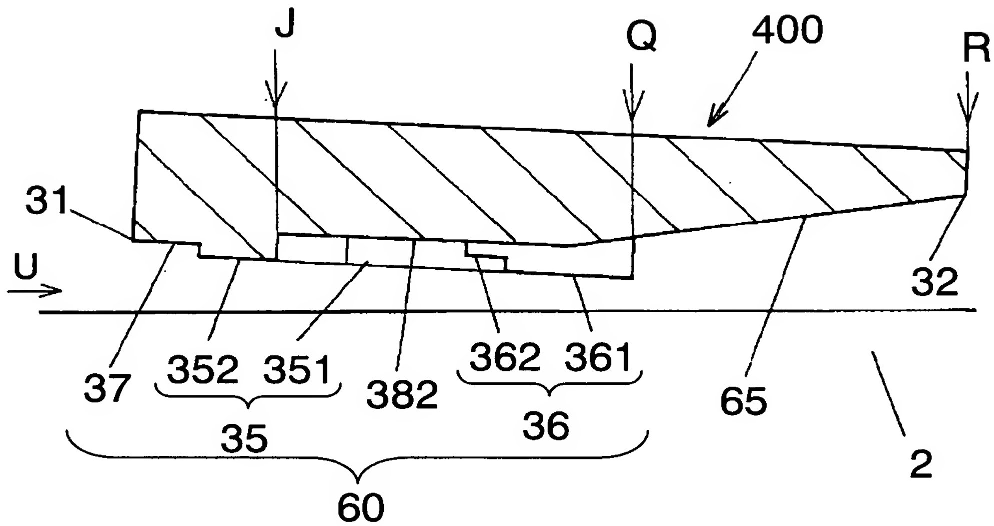

J
Q
400
R
31
U
32
37
352
351
382
362
361
65
35
36
2
60

FIG. 8B

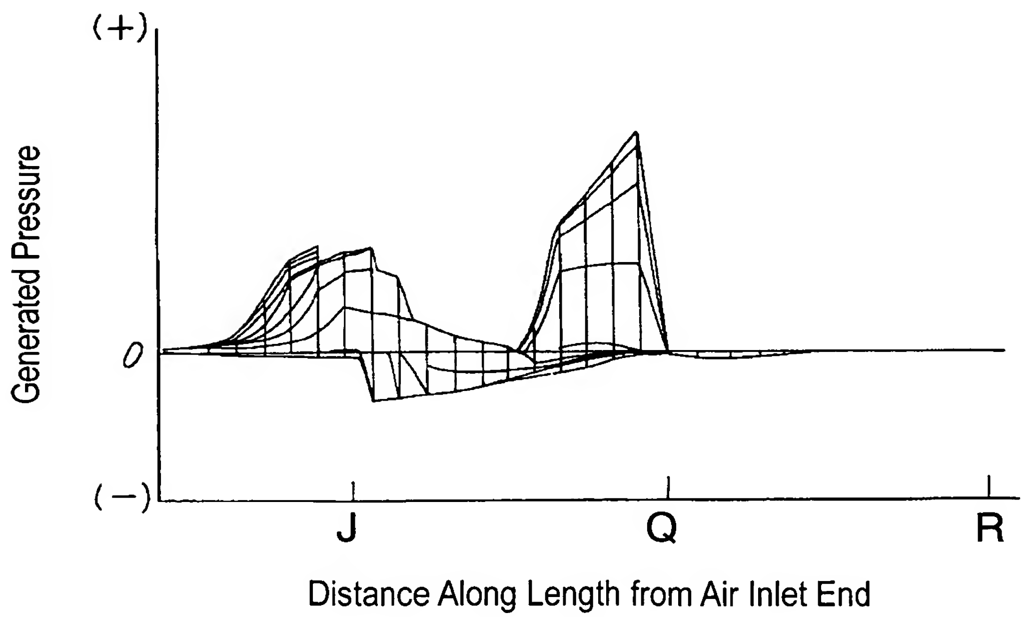

(+)
0
(−)
Generated Pressure
J
Q
R
Distance Along Length from Air Inlet End

FIG. 9A

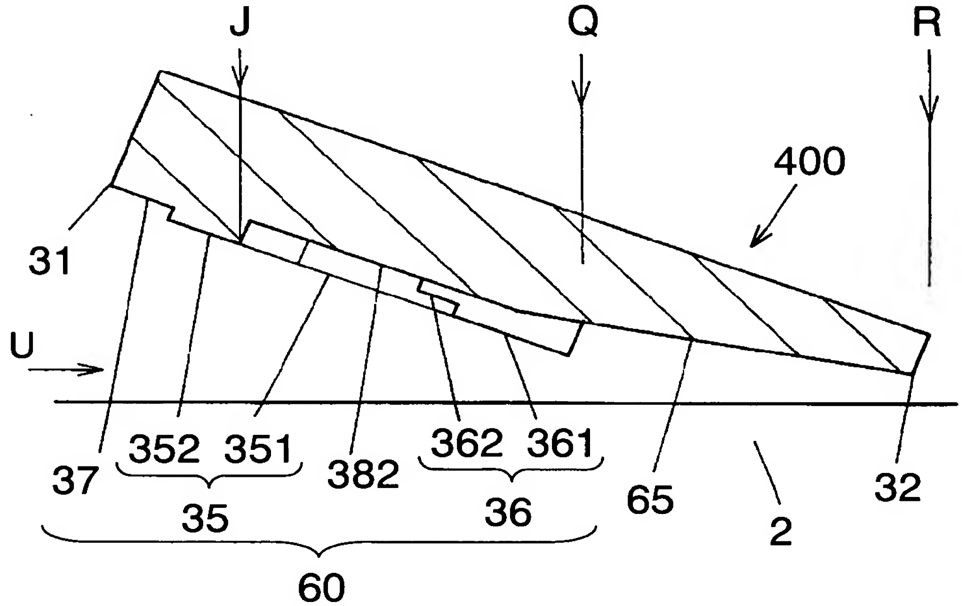

J
Q
R
400
31
U
37
352
351
35
382
362
361
36
60
65
2
32

FIG. 9B

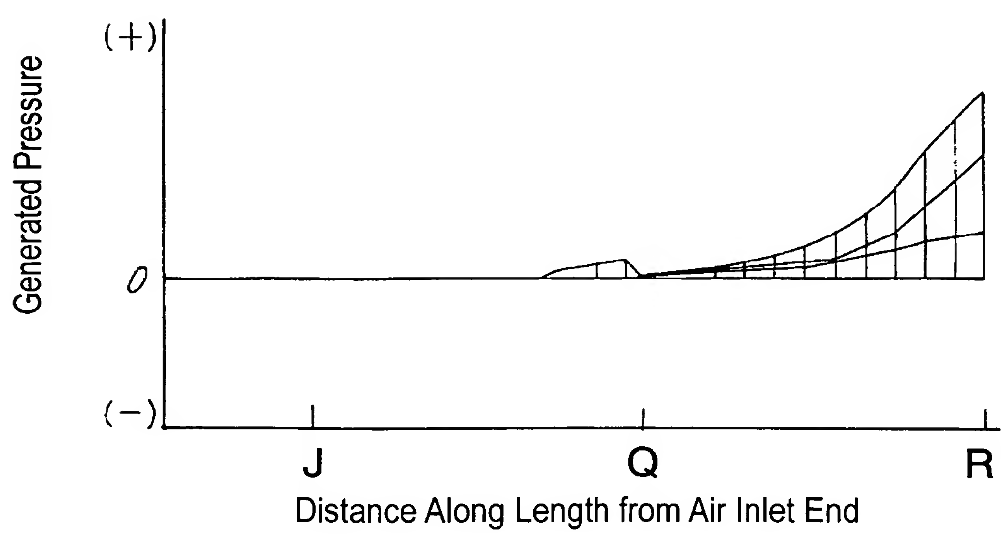

(+)
0
(−)
Generated Pressure
J
Q
R
Distance Along Length from Air Inlet End

FIG. 10

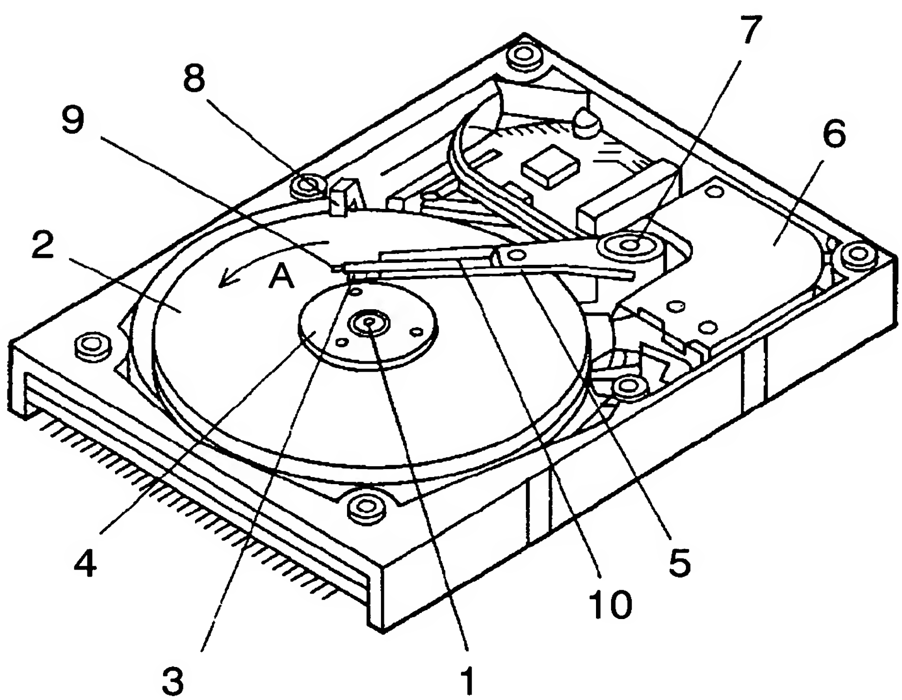


FIG. 11A
PRIOR ART

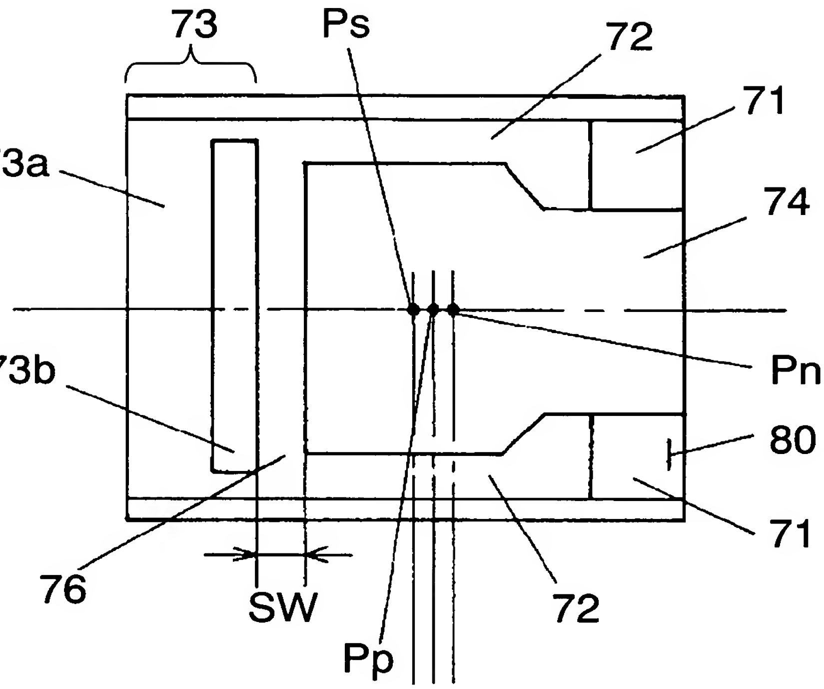


FIG. 11B
PRIOR ART

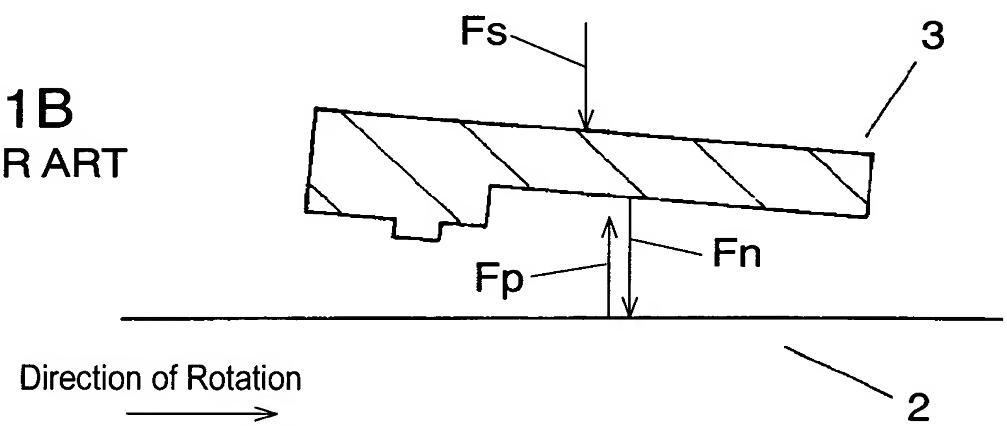


FIG. 12A

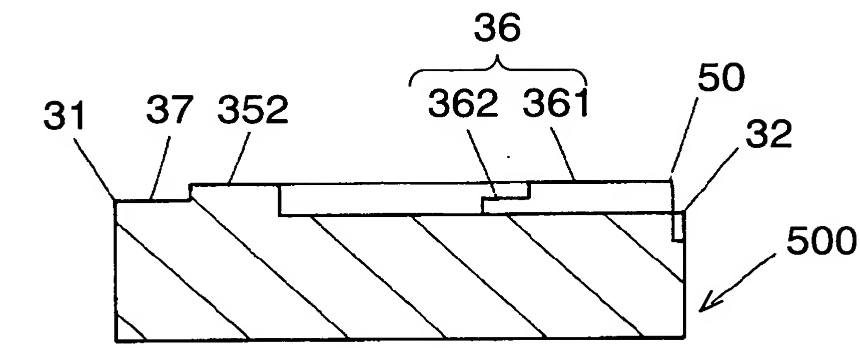


FIG. 12B